FUNCTIONAL EVALUATION AND OVERLAY DESIGN OF EXISTING FLEXIBLE PAVEMENT: A CASE STUDY OF KARNI & KHARA INDUSTRIAL AREA ROAD BIKANER

Ms. Harshita Mehta[1], Dr. Pratibha Choudhary[2], Mrs. Akshita Choudhary[3], Mr. Natwar Singh[4]

[1]B.Tech student, Dept. of Civil Engg. , GCET, Bikaner
[2]Head, Dept. of Civil Engg. , GCET, Bikaner
[3]Asst. Professor, Dept. of Civil Engg. , GCET, Bikaner
[4]Faculty, Dept. of Civil Engg. , GCET, Bikaner

Abstract –*Road transportation constitutes a major portion in the overall transportation system. With the increase in the traffic volume, there is observatory increase in the distress of the pavement structure, which in turn causes excessive deterioration. With time, the failure goes on increasing gradually due to overloading of axles and significant variations in daily and seasonal temperature of the pavement which is thus responsible for early development of distress symptoms like potholes, rutting, cracks, undulations, bleeding, raveling and shoving of bituminous surfacing. Thus the evaluation of the condition of the pavement becomes quite necessary to choose appropriate improvement technique that has to be implemented to improve the quality and strength of the pavement structure. The performance evaluation consists of functional as well as structural evaluation. This paper presents a review on structural and functional evaluation of flexible pavement and analyzes the condition of the pavement which includes relevant data like soil sub grade data, existing pavement structure, traffic data, pavement surface condition and rebound deflection by using BBD technique, laboratory investigations and finally the design of the overall thickness of the pavement and overlay, required to strengthen the road stretches. The paper also includes the comparison between the existing and the newly designed pavement thickness. Conclusions are also drawn from the overall study conducted on the road stretches followed by some useful recommendations.*

Keywords: Functional distress, Structural Fatigue, Functional evaluation, Structural evaluation, BBD technique, Overlay design, Design of roads, Rebound deflection

1. INTRODUCTION

Road transport plays a chief role in the overall transportation system, because of various advantages like, door to door service, flexibility, easy availability, and many more. Hence, it becomes necessary to provide a good road network for the development of any country. Pavements once constructed needs periodic inspection for maintenance purpose. Since reconstruction of the damaged pavements is very expensive and can highly affects the economy of the country, strengthening method is highly adopted worldwide as a pavement maintenance measure.

A distressed pavement requires considerable maintenance. The maintenance expenditure can be reduced through following ways such as proper planning, designing, construction and quality control. If the causes of possible distress are removed, or judiciously taken care of, during design stage, the expenditure due to maintenance measures on in-service roads gets reduced to a great extent. The paper analyzes the method of flexible pavement strengthening by Benkelman Beam Deflection technique. The entire methodology and parameters involved in this technique are taken care of and lastly, the design aspects of pavement

strengthening are also put forward. This work is an attempt to study the BBD technique fully and then to deduce the useful conclusions from the study and apply in the field for the strengthening of in-service pavements.

The paper reviews the strength of the existing pavement structure and provides the new pavement design and quantitative measures which have to be taken while the construction of the pavement.

2. OBJECTIVE OF THE STUDY

The main objectives of the study are –

1. Evaluation of the pavement condition to choose appropriate improvement technique and equipments to improve the quality and strength of the pavement structure.
2. Collection of relevant data like soil sub grade data, existing pavement structure, traffic data and rebound deflection by using BBD technique.
3. To compute the overall thickness of the pavement and design of overlay.

3. STUDY AREA

The scope of study is limited to two stretches of road each of 1 km long. The stretch 01 is from Karni Industrial area and stretch 02 is from Khara Industrial Area. Study area stretches were selected based on the category of the road, terrain and traffic conditions, geographical location etc. These stretches can be named as Site 01 and Site 02.

Site 01:

In the year 1991, when land stock of both the phases of Industrial Area Bichchwal was leading to exhaust; a loud demand for another phase was immerging up among the entrepreneurs of Bikaner city. Existing Industrial Area Bichchwal was surrounded by NH-15 / RAC Line in the East, Central Arid Zone Research Centre (CAZRI) in the West, Central Sheep and Wool Research Institute (CSWRI) in the North and Indira Gandhi Nahar Pariyojna (IGNP) colony in South. There was no way out other than to go on Pugal road in region already marked as industrial land use in Master Plan of Bikaner city.

Karni Industrial Area is situated on SH-3 leading to Chhatargarh. The distance from Bikaner city is only 5 kms.

Site 02:

The Ministry of Industry, Department of Industrial Development, Govt. of India approved 5 Growth Centers in Rajasthan. I.G.C. Khara, Bikaner is one of those five growth centers. This area was established in the year 1992 and was also approved by Government of India in the same year. This area has been established for the development of mineral, wool, ceramics, food products & agro-based industries.

Khara is situated at 18 kms from Bikaner on NH-15 leading to Shri Ganganagar.

The climate in the study region is low rainfall, extreme diurnal and annual temperature, low humidity and high-velocity winds.

Summer-March, April, May

Monsoon-June, July, August

Post monsoon-September, October, and November

Winter-December, January, February

The table below shows the details of study stretches –

Table 1 – Details of Study stretches

S.No.	Name of the road	Category	Terrain
1	Karni Industrial Area Road	SH	Plain
2	Khara Industrial Area Road	NH	Plain

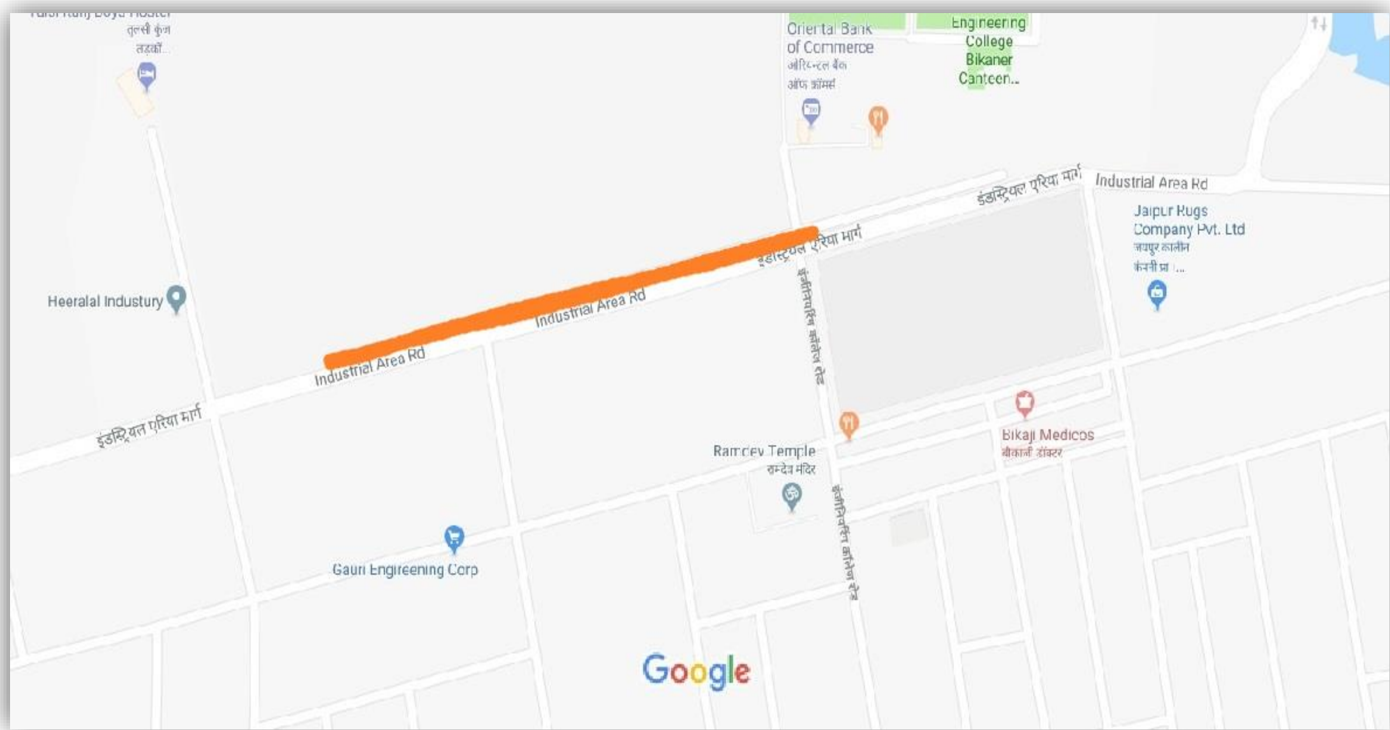

Figure 1 – Karni Industrial Area Road Stretch

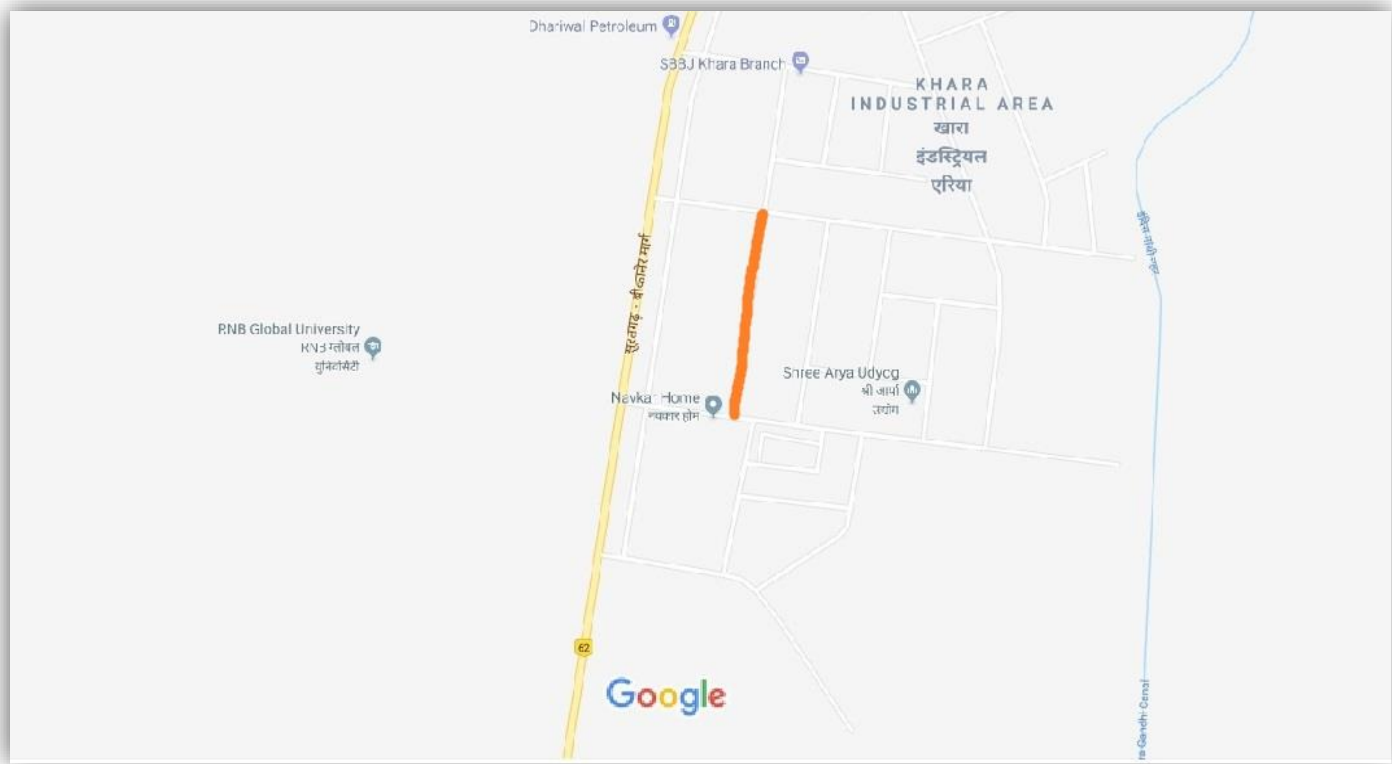

Figure 2 - Khara Industrial Area Road Stretch

4. EVALUATION OF FLEXIBLE PAVEMENT

Pavement evaluation is a very important part of the pavement strengthening method adopted. Pavement evaluations are conducted to determine both functional and structural conditions of a highway section. Functional condition is concerned with the ride quality or surface texture of a highway section. Structural condition is concerned with the structural capacity of the pavement which can be measured by deflection, layer thickness and material properties. The pavement evaluation is necessary at periodic intervals, especially at important road sections as the chosen one. Thus various evaluation tests such as BBD test, needs to be carried out to examine the current condition of the road section.

- **Structural Evaluation:** Structural evaluation of pavement deflection is the structural property of the pavement. Benkelman Beam is used to evaluate the structural properties of the pavement (as per IRC: 81 – 1997). This method has been most widely adopted in India.
- **Functional Evaluation:** Pavement condition survey and/or Roughness survey is carried out to evaluate functional properties of pavement. Pavement roughness is defined as an expression of irregularities in the pavement surface that adversely affect the ride quality of a vehicle.

5. PAVEMENT CONDITION ASSESSMENT UNDER INVESTIGATION

5.1 Pavement Condition Survey (PCS)

In accordance with IRC: 81-1997 (Clause 4.2), this phase of operation, which precedes the actual deflection measurement, consists primarily of visual observations supplemented by simple measurements

for rut-depth using a 3-meter straight edge. Based on these, the road length shall be classified into sections of equal performance in accordance with the criteria given in the table.

Table 2 – Criteria for Classification of Pavement Sections

Classification	Pavement condition
Good	No cracking, rutting less than 10 mm
Fair	No cracking or cracking confined to single crack in the wheel track with rutting between 10 mm to 20 mm
Poor	Extensive cracking and/or rutting greater than 20 mm. Sections with cracking exceeding 20% shall be treated as failed.

Result –

Site 01 – In this site, there are negligible ruts, cracking or any other road distresses, this part is good from PCS point of view.

Site 02 – In this site, there are some visible ruts, cracking or any other road distresses, this part is fair from PCS point of view.

5.2 Pavement Structure Survey (PSS)

Site 01 – The existing crust of pavement layers is 150 mm GSB, 250 mm WBM.

Site 02 – The existing crust of pavement layers is 150 mm GSB, 250 mm WBM.

The existing road is highly in distress condition due to increase in traffic. As the industrial area is saturated and most of the industries are in production, hence the heavy traffic is increased. The road needs strengthening by providing overlay thickness.

6. DATA COLLECTION

6.1 Laboratory Investigation

The sub-grade soil samples were collected from three different locations of the road and following tests were carried out:

Table 3 – Laboratory test results for site 01

	Sample 1	Sample 2	Sample 3
Moisture Content	1.23%	1.23%	1.23%

Plasticity Index	NP	NP	NP
CBR value (As per RIICO)	7.3%	7.3%	7.3%

But considering the code, CBR value is taken as 7 % for the ease of calculations and design.

Table 4 - Laboratory test results for site 02

	Sample 1	**Sample 2**	**Sample 3**
Moisture Content	1.12 %	1.12 %	1.12 %
Plasticity Index	NP	NP	NP
CBR value (As per RIICO)	8.03%	8.03%	8.03%

But considering the code, CBR value is taken as 8% for the ease of calculations and design.

6.2 Traffic Survey

The design traffic is considered in terms of the cumulative number of standard axles to be carried during the design life of the road. Its computation involves estimates of the initial volumes of commercial vehicles per day, lateral distribution of traffic, the growth rate, the design life in years and the vehicle damage factor (number of standard axle per commercial vehicle) to convert commercial vehicles to standard axles.

Table 5 – Three day traffic count of Site 01

Day	Vehicles Class									Total
	Car, Jeeps, Vans, Three-Wheelers	Motorized Two Wheelers	Light Commercial Vehicles	Trucks	Agricultural Tractors/ Trailers	Buses	Cycles	Cycle Rickshaws	Animal Drawn Vehicles	
Day 1 (25.07.17)	935	1,864	326	227	172	9	295	--	44	3,872
Day 2 (26.07.17)	784	1,485	327	117	120	5	306	--	16	3,160
Day 3 (27.07.17)	887	1,287	368	167	113	12	276	--	22	3,132
Total	2,606	4,636	1,021	511	405	26	877	--	82	10,164
Average Daily Traffic	869	1,545	340	170	135	9	292	--	27	3,388
PCU Factor	1.0	0.5	1.5	3.0	3.0	3.0	0.5	2.0	4.0 for Horse Drawn 8.0 for Bullock Drawn	
Average Daily Traffic PCU's	869	773	510	510	405	27	146	0	216	3,456
Total CVPD			340	170	135	9				654

Table 6 – Three day traffic count of Site 02

Day	Vehicles Class									Total
	Car, Jeeps, Vans, Three-Wheelers	Motorized Two Wheelers	Light Commercial Vehicles	Trucks	Agricultural Tractors/ Trailers	Buses	Cycles	Cycle Rickshaws	Animal Drawn Vehicles	
Day 1 (25.07.17)	530	1,012	193	163	340	1	41	--	1	2,281
Day 2 (26.07.17)	470	970	167	186	343	--	43	--	2	2,181
Day 3 (27.07.17)	426	843	170	239	249	--	45	--	1	1,973
Total	1,426	2,825	530	588	932	1	129	--	4	6,435
Average Daily Traffic	475	942	177	196	311	0	43	--	1	2,145
PCU Factor	1.0	0.5	1.5	3.0	3.0	3.0	0.5	2.0	4.0 for Horse Drawn 8.0 for Bullock Drawn	
Average Daily Traffic PCU's	475	471	267	588	933	0	22	--	8	2,764
Total CVPD			177	196	311	0				684

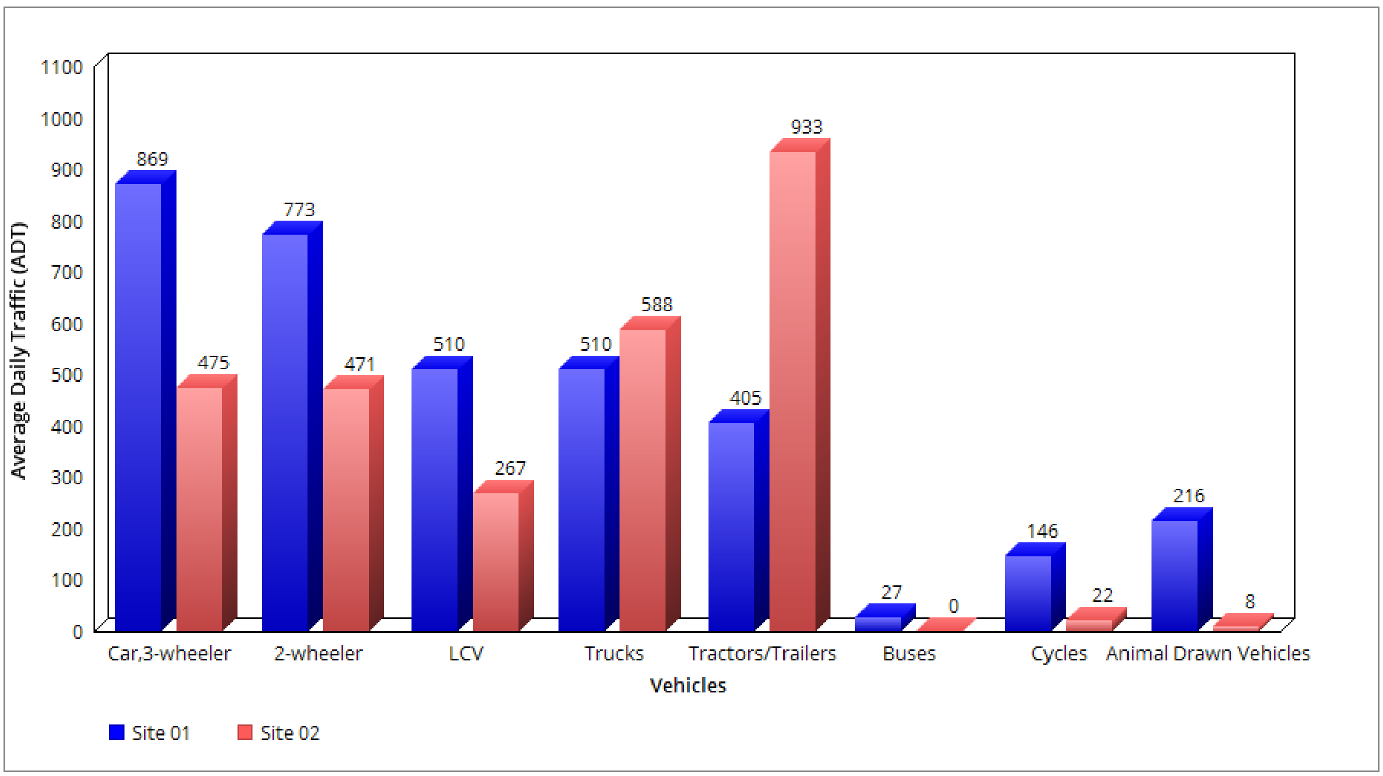

Figure 3 – Average Daily Traffic (ADT) for both the sites

From the 3-day 24 hour traffic survey for each site, the total commercial vehicle per day for site 01 is 654 vehicles/day (≥3 tons) and that for the site 02 its value is 684 vehicles/day (≥ 3tonns). For design traffic, CVPD values are used in the formula and the final traffic result is computed in terms of Million Standard axles (msa). The values of design traffic come out to be:

- For Site 01 = 8.7 msa
- For Site 02 = 6.3 msa

The values of CBR and traffic data obtained are then used in the recommended graphs of IRC: 37-2001 (Figure: 1) to deduce the value of overall thickness of the pavement.

The overall thickness of the pavement comes up to be –

- For Site 01 = 560 mm
- For Site 02 = 490 mm

7. EXPERIMENTAL SET-UP OF BENKELMAN BEAM DEFLECTION EQUIPMENT

The Benkelman beam measures the deflections under standard wheel load conditions. The beam is a handy instrument which is most widely used for measuring deflection of pavements. The instrument is shown in diagram. It consists of a lever 3.66 m long pivoted 2.44 m from the end carrying the contact point which rests on the surface of the pavement. The deflection of the pavement surface produced by the test load is transmitted to the other end of the beam where it is measured by a dial gauge or recorder. The movement at the dial gauge end of the beam is one-half of that at the contact point end. The load on the dual wheel can be in the range of 2.7 to 4.1 Tones.

Figure 4 – Benkelman beam deflection equipment

7.1 Equipment used in survey:

1. Thermometer	2. Truck
3. Auger	4. Benkelman Beam
5. Mandrel	6. Dial Gauge
7. Glycerol	8. Tape

8. PAVEMENT DEFLECTION MEASUREMENT

8.1 Three types of data are required for knowing the deflection:

1. Temperature data:

The standard temperature for doing the experiment is 35°C. Since it is not possible to conduct the test at the standard temperature, a correction factor has to be applied for the deflection. The correction factor is determined by knowing the temperature at the time of the survey. If the depth of the BT surface is more than 40mm, then correction factor has to be applied. If the depth is less i.e. if it is a thin bituminous surfacing, then no correction is required.

The procedure for determining the temperature is given below –

a) A hole is drilled into the pavement with the help of a mandrel. The depth of the hole is 45 mm and the diameter of the hole at the top is 1.25 cm and at the bottom is 1 cm.

b) The hole is then filled with glycerol and the temperature is recorded after 5 minutes with the thermometer (range of temperature between 0° -100°) with 1° division.

c) The temperature readings are measured for every hour during the survey.

2. Soil data:

Deflection measurements should be made during the monsoons when the pavement is in its weakest condition. Hence a correction for seasonal variation has to be applied for the deflection which is a function of the soil sub-grade. The data required are:

a) Average annual rainfall in that area

b) Soil classification – sandy / gravelly, clayey with low plasticity and clayey with high plasticity.

c) Field moisture content.

The procedure for soil collection is given below –

Make a test pit in the shoulder to a depth up to 15 cm below the sub-grade level in every km. Using an auger collect the soil sample from the sub-grade beneath the deflection points (These are the points which are at a distance of 0.6m from the edge of the pavement if the carriageway width < 3.5 m {single-lane road}; 0.9 m if the carriageway width is greater than 3.5 m {Two-lane road} and 1.5 m if it is a four-lane road).

3. ***Truck specifications for conducting the test:***

Rear axle weight of the truck = 8170 kg

Tyre pressure = 5.6 kg / cm^2

The spacing between the tyre walls = 30 -40 mm.

Table 7 - Summary of field deflections for site 01

Name of road – Karni Industrial Area road **No. of lanes – 2** **Air temperature – 35°C**					**Date and time of observation – 28/07/2017 at 14:00 hrs** **Climatic condition – Sunny** **Pavement temperature – 35°C**			
S.No.	**Location of test points and identify- -cation of lanes**	**Pavement temperature (°C)**	**Type of soil and PI**	**Moisture content %**	**Dial Gauge Reading (mm)**			**True pavement Deflection (X_T) (mm)**
					Initial	**Interme- -diate**	**Final**	
1.	00/00-03/00	35°C	Sandy/ gravelly NP	1.23%	24.41	24.34	24.20	1.23
2.	03/00-12/00				16.40	16.29	16.14	1.39
3.	12/00-22/00				46.50	46.37	46.24	1.27
4.	22/00-32/00				21.50	21.38	21.23	1.41
5.	32/00-42/00				29.40	29.32	29.17	1.35
6.	42/00-52/00				22.48	22.37	22.24	1.27
7.	52/00-62/00				21.90	21.85	21.71	1.22
8.	62/00-72/00				15.08	14.96	14.81	1.41
9.	72/00-82/00				31.77	31.66	31.52	1.34
10.	82/00-92/00				14.27	14.23	14.07	1.36
11.	92/00-102/00				18.72	18.66	18.51	1.31
12.	102/00-112/00				25.23	25.17	25.01	1.40
13.	112/00-122/00				27.77	27.69	27.55	1.30

Table 8 - Summary of field deflections for site 02

Name of road – Khara Industrial Area road **No. of lanes – 2** **Air temperature – 35°C**					**Date and time of observation – 28/07/2017 at 16:00 hrs** **Climatic condition – Sunny** **Pavement temperature – 35°C**			
S.No.	**Location of test points and identify--cation of lanes**	**Pavement temperature (°C)**	**Type of soil and PI**	**Moisture content %**	**Dial Gauge Reading (mm)**			**True pavement Deflection (X_T) (mm)**
					Initial	**Interme--diate**	**Final**	
1.	00/00-03/00	35°C	Sandy/ gravelly NP	1.12%	28.59	28.55	28.42	1.10
2.	03/00-12/00				15.48	15.37	15.23	1.31
3.	12/00-22/00				25.30	25.17	25.04	1.27
4.	22/00-32/00				18.72	18.62	18.46	1.45
5.	32/00-42/00				18.25	18.15	18.02	1.20
6.	42/00-52/00				27.77	27.65	27.54	1.13
7.	52/00-62/00				31.23	31.19	31.03	1.37
8.	62/00-72/00				14.25	14.17	14.01	1.40
9.	72/00-82/00				29.46	29.32	29.21	1.15
10.	82/00-92/00				22.48	22.28	22.18	1.21
11.	92/00-102/00				16.31	16.29	16.14	1.23
12.	102/00-112/00				21.29	21.26	21.10	1.30
13.	112/00-122/00				15.08	14.94	14.81	1.32

Table 9 – Characteristic deflection table for site 01

Location of test point	Measured Deflection (mm)	Correction for temp- -erature (mm)	Correction for seasons (mm)	Corrected Deflection (mm)	Mean Deflection (mm)	Standard Deviation (mm)	Characteristic deflection (mm)	Design Traffic (msa)
00/00-03/00	1.23	--	--	1.23	1.33	0.02	1.35	8.7
03/00-12/00	1.39			1.39				
12/00-22/00	1.27			1.27				
22/00-32/00	1.41			1.41				
32/00-42/00	1.35			1.35				
42/00-52/00	1.27			1.27				
52/00-62/00	1.22			1.22				
62/00-72/00	1.41			1.41				
72/00-82/00	1.34			1.34				
82/00-92/00	1.36			1.36				
92/00-102/00	1.31			1.31				
102/00-112/00	1.40			1.40				
112/00-122/00	1.30			1.30				

Table 10 – Characteristic deflection table for Site 02

Location of test point	Measured Deflection (mm)	Correction for temp- -erature (mm)	Correction for seasons (mm)	Corrected Deflection (mm)	Mean Deflection (mm)	Standard Deviation (mm)	Characteristic deflection (mm)	Design Traffic (msa)
00/00-03/00	1.10	--	--	1.10	1.26	0.031	1.30	6.3
03/00-12/00	1.31			1.31				
12/00-22/00	1.27			1.27				
22/00-32/00	1.45			1.45				
32/00-42/00	1.20			1.20				
42/00-52/00	1.13			1.13				
52/00-62/00	1.37			1.37				
62/00-72/00	1.40			1.40				
72/00-82/00	1.15			1.15				
82/00-92/00	1.21			1.21				
92/00-102/00	1.23			1.23				
102/00-112/00	1.30			1.30				
112/00-122/00	1.32			1.32				

Result –

On performing the pavement deflection measurements using BBD technique, the characteristic deflection comes up to be –

- For Site 01 = 1.35 mm
- For Site 02 = 1.30 mm

9. OVERLAY DESIGN FOR FLEXIBLE PAVEMENT

Using the values of characteristic deflection to design the overlay for strengthening of the two selected sites the thicknesses as per the recommended graph of IRC: 81-1997 (Figure: 9), came out to be –

- For Site 01 = 90 mm
- For Site 02 = 80 mm

As per IRC: 37-2001 (plate 1), recommended pavement design for traffic range 1 – 10 msa for two selected sites, is given below –

Table 11 - Recommended pavement design for traffic range 1 – 10 msa for Site 01

CBR 7%					
Cumulative Traffic (msa)	Total pavement thickness (mm)	PAVEMENT COMPOSITION			
		Bituminous Surfacing		Granular Base (mm)	Granular Sub-base (mm)
		Wearing Course (mm)	Binder course (mm)		
1	375	20 PC	--	225	150
2	425	20 PC	50 BM	225	150
3	460	20 PC	50 BM	250	160
5	505	25 SDBC	50 DBM	250	180
10	580	40 BC	60 DBM	250	230

Table 12 - Recommended pavement design for traffic range 1 – 10 msa for Site 02

CBR 8%					
Cumulative Traffic (msa)	Total pavement thickness (mm)	PAVEMENT COMPOSITION			
		Bituminous Surfacing		Granular Base (mm)	Granular Sub-base (mm)
		Wearing Course (mm)	Binder course (mm)		
1	375	20 PC	--	225	150
2	425	20 PC	50 BM	225	150
3	460	20 PC	50 BM	250	160
5	505	25 SDBC	50 DBM	250	180
10	580	40 BC	60 DBM	250	230

Table 13 – Pavement composition for Site 01

Pavement Composition	Allowable thickness
GSB	220 mm
GB (WMM)	250 mm
Bituminous Surfacing	
Wearing Course (BC)	40 mm
Binding Course (DBM)	50 mm

Table 14 – Pavement Composition for Site 02

Pavement Composition	Allowable thickness
GSB	160 mm
GB (WMM)	250 mm
Bituminous Surfacing	
Wearing Course (BC)	30 mm
Binding Course (DBM)	50 mm

10. ANALYSIS AND RESULT

In table 15 and table 16, the existing and the proposed crust for both the sites have been compared and thus the overlay thickness is deduced.

In the figure given below, the new pavement thickness is designed for both the sites.

Table 15 – Comparison of existing and proposed crust for Site 01

Existing Crust	Proposed Crust
GSB – 150 mm WBM – 250 mm Total – 400 mm	GSB – 220 mm WBM – 250 mm DBM – 50 mm B.C – 40 mm Total – 560 mm

Table 16 - Comparison of existing and proposed crust for Site 02

Existing Crust	Proposed Crust
GSB – 150 mm WBM – 250 mm Total– 400 mm	GSB – 160 mm WMM – 250 mm DBM – 50 mm BC – 30 mm Total –490 mm

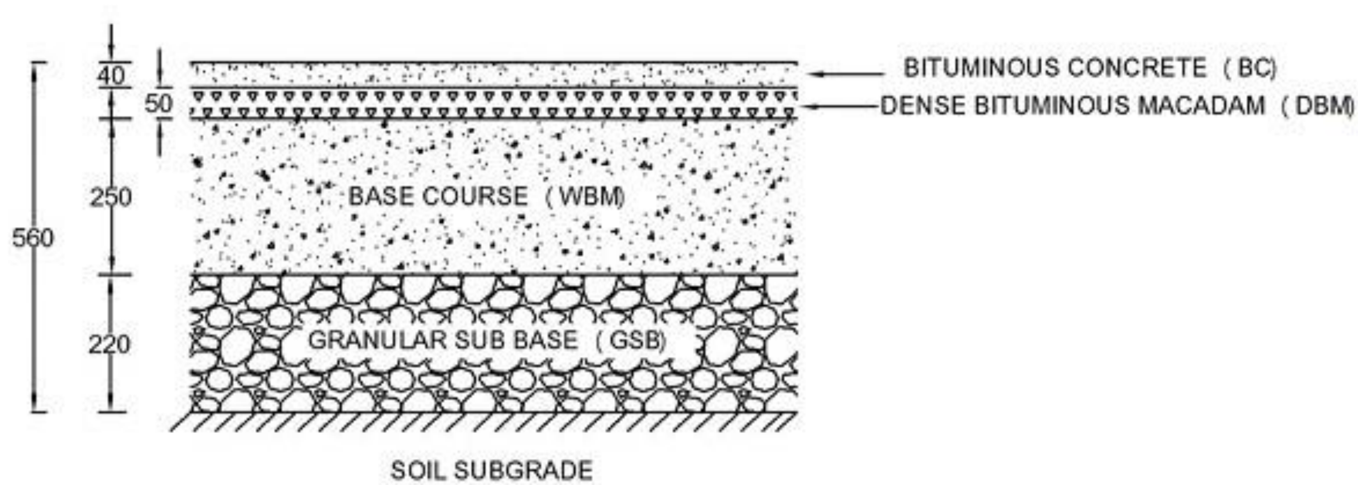

Figure 5 – Newly designed pavement thickness for site 01

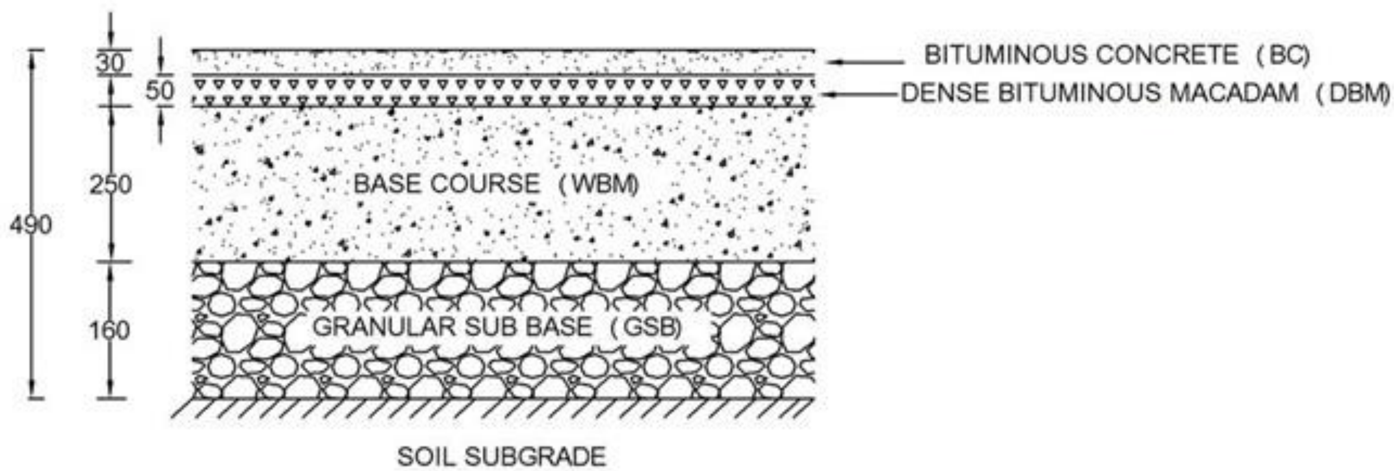

Figure 6 – Newly designed pavement thickness for site 02

11. CONCLUSION

1. It is advisable to implement the necessary maintenance measures at an early stage when the distresses have just started showing up. It is seen that proper pavement measures at an early onset of distresses, can obviate major maintenance expenditure in future. This is because, in general, the rate of deterioration increases with time.
2. Out of all the deflection measuring methods, the BBD method is the most simple and reliable method.
3. This method is used to measure the rebound deflection of pavement under static load.
4. The correction of temperature is needed when bituminous layer is appreciably thick and temperature is standardized to 35°C.

12. RECOMMENDATION

1. Periodic maintenance procedures should be implemented so as to maintain the design serviceability and increase the life span of the pavement.
2. While designing the new pavements, proper investigation and IRC guidelines should be followed.
3. The infill used must be of desired characteristics which can be fully compacted with ease to attain the required strength.
4. Proper camber and shoulders should be present.
5. There should be coordination between the various agencies responsible for lying of utilities and the construction of roads.
6. It is also recommended that the characteristic deflections obtained in different sections of roadway from BBD testing should be appropriately used for strengthening the roadway by providing suitable thickness as per the code of design, or practice followed.

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